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Before the
Federal Communications Commission

In the matter of Advanced Television Systems and Their Impact upon the Existing Television Broadcast Service	)))))	MM Docket No. 87-268

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FEDERAL COMMUNICATIONS COMMISSION
OFFICE OF THE SECRETARY

COMMENTS OF S. MERRILL WEISS, CONSULTANT

1. S. Merrill Weiss, Consultant in Electronic Media Technology/Management, an interested party in this proceeding, respectfully submits these comments in response to the invitation contained in the Memorandum Opinion and Order/Third Report and Order/Third Further Notice of Proposed Rulemaking released on October 16, 1992.

2. As an individual who has spent a major part of the past five years working in a number of areas within the Advisory Committee on Advanced Television Service, these comments are offered in the hope that they may be of some help to the Commission in assessing the impact of its proposals on broadcasters, in general, and on their eventual implementation of Advanced Television, in particular. My credentials in offering these comments include twenty-five years experience within the broadcast industry designing, building, and managing the technical operations of a number of television and radio stations. Since early 1988, I have served on the Advisory Committee as Vice Chairman and Acting Chairman of Implementation Subcommittee Working Party 2 on Transition Scenarios (IS/WP-2), as a member of Systems Subcommittee Working Party 1 on Systems Analysis (SS/WP-1), as an invited member of the SS/WP-1 Task Force on Systems Analysis, as a member of Systems Subcommittee Working Party 3 on Economic Analysis (SS/WP-3), and as a participant on the Systems and Implementation Subcommittees. I have also been involved for the past fifteen years in the development of standards for television and particularly digital television, through the Society of Motion Picture and Television Engineers (SMPTE), having been chairman of a number

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of the SMPTE technology committees and having been responsible for a number of the tests and demonstrations that have led to international standards. I am a Fellow of SMPTE and a Certified Professional Broadcast Engineer of the Society of Broadcast Engineers (SBE). I am a graduate of the Wharton School of Economics and Finance of the University of Pennsylvania. I am currently active as a consultant in the area of electronic media technology and technology management and expect to make a substantial part of my livelihood in the future through assisting broadcasters and others in their transitions to Advanced Television (ATV). I maintain offices at 25 Mulberry Lane, Edison, NJ 08820-2908.

3. In these comments I will address specific implementation issues discussed within the Notice about which studies have been undertaken within the Advisory Committee but that have not been completed in sufficient time to meet the deadline for adoption by the Advisory Committee. This work is of substantial value and should be considered by the Commission even though it has not reached the point of decision and publication by the Advisory Committee because of the lack of time. I will also comment on related technologies that are inextricably linked with the issues under consideration and about which the Commission has also sought input.

I. BACKGROUND

4. Since the time of the first proposal for a digital transmission system for Advanced Television (ATV), there has been discussion among experts in the industry concerning alternative approaches to facilitating such a system. The techniques that are necessary to support any of the systems proposed to date, including such methods as adaptive equalization and forward error correction, might make possible the use of multiple transmitters on a single frequency, as opposed to the current universal use of a single central transmitter. These approaches may offer opportunities for broadcasters faced with particular implementation situations to overcome difficulties that otherwise might lead to less than optimum service to the public. At the same time, they may have

operational difficulties of their own that must be understood before consideration can be given to their application.

5. In looking at ATV implementation, Implementation Subcommittee Working Party 2 (IS/WP-2) on Transition Scenarios of the Advisory Committee undertook to study what has come to be called the distributed transmission concept. This study was at least partially instigated by inclusion of the approach in the certification documentation submitted by the American Television Alliance for the Channel Compatible DigiCipher (CC-DC) system. IS/WP-2 made significant progress in understanding the issues, the strengths, and the weaknesses of distributed transmission. It also enlisted the help of Systems Subcommittee Working Party 1 (SS/WP-1) on Systems Analysis to carry out technical investigations on the subject. Both groups failed to complete the work because of time constraints, but sufficient understanding was gained to make it worthwhile to report what was learned. Especially since the Commission indicated in the Notice that it was awaiting the outcome of the IS/WP-2 and SS/WP-1 studies before undertaking any further consideration of its own on the matter, IS/WP-2 agreed at its final meeting that the information should be conveyed in the form of these comments.

6. Very much related to the concept of distributed transmission is the concept of single frequency networks (SFNs). These have been discussed in the context of a distribution mechanism to feed multiple distributed transmitters. Often associated with SFNs is the digital transmission technology called Coded Orthogonal Frequency Division Multiplex (COFDM). COFDM has been proposed by some as the best means to overcome some of the limitations that will be pointed out below regarding distributed transmission using the systems currently under examination by the Advisory Committee. Without drawing any conclusions about the overall technical validity of COFDM as a transmission method, an attempt will be made in these comments to elucidate some of the issues that will have to be addressed if COFDM is considered as an alternative channel coding scheme.

7. The terms "cellular television" and "cellular transmission" have sometimes been applied in discussions of the use of multiple transmitters to cover the service area of an individual broadcast station. While they provide a conceptual parallel to the physical arrangement of multiple transmitters covering relatively small areas, these terms are assiduously avoided in this discussion because of their implications about the use of multiple channels to provide service in adjacent cells, with those channels being reused on the basis of a fixed pattern of repetition. The distributed transmission to be discussed herein involves the use of only one channel within a given service area. Nonetheless, use of the term "cell" will be made at times when it provides the best understanding. No connection with true cellular operation should be inferred from such usage.

II. RATIONALE FOR DISTRIBUTED TRANSMISSION

8. There are several reasons why distributed transmission may be of interest. These include matters ranging from the amelioration of situations in which broadcasters have difficulty in installing ATV transmitters, to permitting larger service areas for stations that are interference-limited in their coverage, to spectrum efficiency claims for certain aspects of such operations. It is important to understand the reasons distributed transmission might be desirable before examining the ways in which it might be utilized.

9. Broadcasters are likely to have two reasons for interest in distributed transmission. First, there will undoubtedly be stations that find it difficult or impossible to construct full transmission facilities on existing towers and that find it equally difficult or impossible to erect new towers or to obtain necessary tower space from others. This problem is expected to be especially acute for smaller stations in larger markets – stations that very often rent space where additional capacity will not easily become available. Such stations are frequently at the mercy of others in regard to the availability of sufficient aperture and wind loading capacity for the installation of additional facilities. Second, depending upon the outcome of the channel allotment and assignment processes, some stations may find themselves sufficiently short-spaced to neighboring co-channel

NTSC stations that their coverage areas are limited either by the interference they receive or by the protection they must provide.

10. Some have also suggested that use of distributed transmission may yield important benefits in terms of spectrum efficiency. Those promoting the notion of improved spectrum efficiency generally assume that all stations operate using this method. The practicality of such an assumption will be discussed later in these comments.

III. FUNDAMENTAL CHARACTERISTICS

11. In looking at how distributed transmission might be implemented, a number of characteristics must be enumerated at the outset. Distributed transmission involves the use of multiple transmitters spread throughout the service area of a television broadcast operation. Because the area to be served by each individual transmitter is relatively small, the transmitters use relatively low powers at relatively low antenna heights. Since the distances covered are comparatively short, the total power for all of the transmitters is considerably less than that required from a single central transmitter to cover the same area.

12. When lower power transmitters are used, smaller antennas and transmission lines are needed. Since one of the principal constraints on any antenna installation is the weight and, particularly, wind loading of the transmission line, usually more so than the antenna itself, using smaller facilities may permit installations on towers that otherwise could not accommodate them. The trade-off to achieve this reduction is that multiple transmission sites must be used to cover the service area – sites that must be obtained, constructed, and maintained. For stations that otherwise could not build facilities or that would end up with substantially reduced coverage, the trade-off may be worthwhile.

13. The use of low power and low height has important implications for interference, especially when considering interference caused to a neighboring station.

The interference zone around a transmitter can be thought of as an anular ring surrounding the service area inside. To a first approximation, the length of the interference zone bears a proportional relationship to the radius of the coverage area. If smaller coverage areas are used for individual transmitters, the proportional interference distance from each transmitter remains essentially the same, but the absolute interference distance becomes smaller. This theoretically permits the service area of a station to approach much closer to a neighboring station while keeping the interference penetration to that neighbor at a constant level.

14. The reasons that distributed transmission might become possible for the first time with ATV are connected with the technology required for digital transmission. Adaptive equalizers are proposed as part of the receiver in each of the digital systems currently under consideration by the Advisory Committee. In addition to the equalizers, each system design includes a substantial amount of error correction overhead to permit forward error correction of the errors remaining after channel equalization. The equalizers and error correction have the effect of overcoming the disturbances caused by echoes (ghosts) arriving at the receiver within certain operating limits. In this sense, the signals from all but one nearby transmitter in a multiple transmitter array are expected to be treated as ghosts by the receiver and effectively eliminated.

IV. MODELS FOR OPERATIONS

15. In order to analyze possible applications of distributed transmission, several models have been developed in which different system attributes are used to define modes of operation. Two particular sets of characteristics allow modelling based on system topologies that would necessarily underlie any potential system designs. These are based on cell size and on signal distribution methods. In each case, two alternatives have been considered.

16. Cell sizes have been categorized along the lines of "large cell" and "small cell" strategies. In the case of large cells, a central transmitter is surrounded by a single

ring comprised of a modest number (4-10) of additional transmitters. In the case of small cells, a much larger number of even lower power transmitters is used. The small cell strategy includes variants ranging from a single ring with many transmitters surrounding a single large transmitter in the middle, to a number of rings surrounding one another with many transmitters, to various grid-positioned networks of transmitters. After intial exploration of both strategies, broadcasters participating in IS/WP-2 indicated a strong preference for the large cell approach based on economic and operational considerations. Further examination of the small cell approach was then curtailed. Small cells were deemed potentially appropriate for filling in gaps in coverage behind obstacles or near specific population targets.

17. Signal distribution was divided between using the cell transmitters to relay signals from one to another in a single frequency network and using a separate distribution network to get the signals from the studio to each of the transmitters. In addition to quite a significant economic impact, the choice between the two distribution methods had far-reaching effects on the transmission characteristics possible or required of each cell. In fact, the choice of distribution approach is directly linked to a number of system design elements that are described in the section on technical factors immediately below.

V. TECHNICAL FACTORS

18. There are a number of interrelated technical factors that bear upon the validity of the distributed transmission approach. These include the number of transmitters and their individual coverage areas, the characteristics of the transmitting antennas, the type of distribution used to deliver the signal to each transmitter, and the capabilities of the adaptive equalizers used in receivers. Each of these will be considered, in turn, with the underlying purpose of showing their interrelationships. In the end, these technical issues bear directly upon the system costs, consumer equipment costs, and competitive matters discussed later in these comments.

19. As discussed previously, the transmission topology was divided among large cell and small cell systems. Large cell systems were defined as those that used a central transmitter surrounded by a small number of additional transmitters in a single ring around the central site. Small cell systems, on the other hand, involved many transmitters in several rings or layers. Small cell systems were studied sufficiently for the broadcasters involved in the work to determine that they were of relatively low interest because of the cost and operational complexity involved in their application. Given this determination, efforts were concentrated on the large cell scheme because of the time and resource constraints in trying to complete the work in the time frame of the Advisory Committee's life. Assistance was requested by IS/WP-2 from SS/WP-1 in analyzing the technical characteristics needed for distributed transmission operations. Two studies were completed by Jules Cohen in support of this work, and copies of his analyses are attached to these comments. In addition, some of the data to be provided later in the discussion was produced by the writer.

20. In the first study, the maximum permissible ATV transmitter power, given the need to protect a nearby (115 miles) NTSC co-channel neighbor, was used as the basis for system design. Under the conditions described in the study, noise-limited ATV coverage of approximately 45 miles is achieved, but, in the direction of the NTSC station, coverage extended only 36 miles because of interference into the ATV signals. A power level of approximately 89 kW ERP at an antenna height of 1000 feet was used to reach this coverage level. A low-power ATV booster was then assumed to be positioned 35 miles from the ATV transmitter in the direction of the NTSC station. In order to maintain approximately the same level of interference to the NTSC signal, an antenna height of 200 feet with an ERP of about 3 kW was possible. This provided an interference-limited extension of the ATV coverage of about 12 miles in the direction of the NTSC station, yielding a total coverage in the direction of the NTSC neighbor of about 47 miles. Under these conditions, it would take eleven equivalent boosters to completely surround the central transmitter, although in directions with no NTSC co-channel stations, larger boosters with greater separations between them are likely to be possible, thereby reducing their number.

21. In the second study, the balance was changed between the central transmitter and the peripheral transmitters to reduce the power in the center and increase it at the periphery. The conditions of the neighboring NTSC co-channel station were unchanged. In this case, the transmitter power was approximately 35 kW at an antenna height of 600 feet, resulting in a noise-limited radius of about 37.5 miles. The booster facility was now limited to approximately 32 kW ERP at 200 feet in order to protect the co-channel NTSC signal. This resulted in an interference-limited coverage of about 18 miles for the booster in the direction of the NTSC station, producing a total coverage of about 48 miles in that direction. A total of four peripheral transmitters would be required to completely surround the central transmitter, and the coverage would be somewhat greater in directions away from the NTSC interference.

22. Two types of antennas are possible in considering distributed transmission systems – omni-directional and directional. The type of antenna that can be used depends upon the type of distribution used to get the signals to the transmitter and upon certain assumptions made about where receiving antennas are pointed. With omni-directional antennas, signals are transmitted back in the direction of the central transmitter. This would only make sense if some proportion of receivers in the area between the central and peripheral transmitters is assumed to be using each transmitter. If this is the case, efforts are likely required to reduce the time difference between the signals arriving at any particular receiver. This is important to the size of the adaptive equalizer, as will be discussed shortly. In order to minimize the time difference, it is necessary to delay the signals from central transmitter, so that they are transmitted at the same time as those of the peripheral transmitters. Since there is a time delay in the distribution to the peripheral transmitters because of the distance to them, the signals to the central transmitter must be delayed a corresponding amount. This means that the signals from the central transmitter cannot be used to distribute the signals to the peripheral tranmitters. In other words, a single frequency network (SFN) is not possible in this case, and alternate means of distribution to the transmitters must be provided. This has serious cost implications to be discussed below.

23. Directional transmitting antennas should be used when receiving antennas inside the peripheral transmitters are assumed to be pointing at the central site. This reduces the signal from the peripheral transmitters arriving at the sides and back of the receiving antennas, thereby reducing the work required of the receiver adaptive equalizers. Directional antennas are also needed when a single frequency network is used for distribution, in order to reduce the amount of peripheral station transmitted signal getting back into the receiving antenna that is ultimately feeding the transmitter, i.e. to reduce feedback. The use of directional antennas (cardioid pattern) was assumed in the studies by Jules Cohen discussed above.

24. Distribution to each of the transmitters of the signals to be broadcast also presents two choices. First, the signals can be relayed over the air, with the output of one transmitter providing the input to the next, as in a single frequency network. Second, the signals can be fed to each transmitter over a separate path. The first (SFN) method provides a signal timing from each transmitter that is dependent on the arrival time of the signals from the previous transmitter in the chain plus the time through the local equipment. The second method, using independent distribution, provides flexible adjustment of the signal timing from each transmitter to optimize the performance of the transmitter network as a whole. The second method would be the preferred choice except for the facts that it requires either a microwave channel and all of the equipment to support it or it requires leasing of circuits from the studio to each of the transmitter sites. The cost impact of the latter approach will be discussed below. The acquisition of microwave channels that can provide distribution to between four and ten sites at distances over 30 miles is extraordinarily difficult in the larger markets, the very places where distributed transmission is most likely to be of benefit. This increases the likelihood that leased circuits would be required in any implementation using a separate distribution path.

25. For systems that use over-the-air relay of the signals to get to outlying transmitters (SFNs), a very serious questions arises about the amount of gain that can be achieved between the receiving antenna, the receiver amplifiers, the transmitter

amplification, and the transmitting antenna before feedback in the system. The amount of gain required to get from the signal levels that will be available from receiving antennas to the power levels that were discussed previously for booster transmitters will be very difficult to achieve in real world situations. Discussions of this have included such techniques as situating antennas on opposite sides of buildings to provide shielding between the transmitting and receiving antennas. This seems unlikely to be adequate, since a helicopter flying into the sidelobes of both antennas simultaneously could cause a very high power oscillation. The isolation provided by a mountaintop might be more appropriate. Another consideration in this regard is the time delay through the booster and the amount of processing that can be achieved to clean up the received signals while keeping that delay to a minimum.

26. The operation of any form of distributed transmission with the ATV systems currently under examination requires the use of receiver adaptive equalizers. The characteristics of those equalizers determine what is possible in the topology of a distributed transmission system and what is required for receiving antennas in such an environment. In particular, the length of echo delays that can be accommodated and the difference in signal levels required for any particular delay between primary signal and echo will determine the performance of the entire system. To a great degree, the capabilities of the adaptive equalizer will be under the control of receiver manufacturers, as opposed to being determined by the ATV system design. The performance of the equalizers tested as part of the Advisory Committee process is instructive, however, in showing the kind of performance that might be achieved. The data was supplied by the proponents in response to specific questions from IS/WP-2 on the subject. In each case, the minimum amplitude difference is required at the minimum time delays, with 6 dB difference generally being required at low delays (in the range up to 4 μsec for one system) and some 10-12 dB being needed at longer delay times (to 24 μsec for the same system).

27. The minimum signal level difference required between a primary signal and an echo can often be provided through the use of a directional antenna at the receiver.

This will be needed most at locations equidistant between a pair of peripheral transmitters. In such a case the field strengths from both would be about the same, or 0 dB. An antenna with a front-to-back or front-to-side ratio of 6 dB or more would provide the separation required. Possibly more difficult would be the situation in which a receive antenna looked "through" the site of a peripheral transmitter and saw the central transmitter behind it. If the central transmitter were too large and the peripheral transmitter too small, in terms of their powers, the receiver might not be able to discriminate between the two signals and treat one as an echo.

28. The maximum time difference with which an equalizer can deal will determine the maximum separations possible between transmitters that have significant signals arriving at any particular receiving location. Thus for the maximum equalizer range quoted by a proponent of 24 μsec, a difference in distances to the two transmitters of only about 4.5 miles can be handled (at 0.1863 miles per microsecond). This assumes that the signals left the two transmitters at the same instant. There is also a factor that describes a signal level difference between primary signal and echo beyond which the echo is of no consequence. This plus the minimum amplitude differences at minimal times and the maximum time difference at significant level differences enter into a complex equation that defines the coverage that can be expected from a given distributed transmission system design. It is beyond the scope of this work and these comments to define that relationship precisely. It is quite important, however, to understand that it exists.

VI. BROADCAST SYSTEM COST COMPARISON

29. As part of its investigations, IS/WP-2 conducted a study of the cost to the broadcaster of different implementations of distributed transmission. In keeping with the decision to concentrate on the large cell approach, this included comparisons between two implementations of a single, central transmitter and two implementations of distributed transmission. Estimates were prepared of the cost to build and the cost to operate each of the kinds of facilities. The single transmitter was analyzed on the basis of both use

of an existing tower and construction of a new tower. Multiple transmitters were analyzed on the basis of eight sites with both leased facilities and owned facilities. It was assumed for the single transmitter that a microwave studio-to-transmitter link (STL) was to be purchased and installed. For the multiple transmitter operations, it was assumed that leased STL channels would be required and that dark fiber would be used. The analysis is detailed in a spreadsheet, a copy of which is attached to these comments.

30. The results of the study showed roughly comparable capital costs for use of a single transmitter with an existing tower ($\approx$\$1.2 million), multiple transmitters with rented space ($\approx$\$1.3 million), and multiple transmitters with construction of towers required ($\approx$\$1.5 million). (The case of a single transmitter with a new tower required was estimated at $\approx$\$2.3 million.) Operating costs were an entirely different matter, however, with the annual cost to operate the single transmitter running well under \$200,000 (either case) and the cost to operate the multiple transmitters ranging between nearly \$700,000 and \$800,000. The operating cost for the multiple transmitter approach was dominated by the cost of the fiber interconnect between sites. This was assumed to be 30 miles per leg, with eight such links. The cost used for this was \$200 per mile per month, a value derived from the average of the tariffs approved for four Regional Bell Operating Companies in a recent FCC tariff proceeding. If this can be converted to microwave that is owned by the station or to some form of interconnection at a lesser rate than dark fiber, these costs can be reduced. A number of possibilities were explored and may be available during the transition to ATV but are not currently available. If the costs of interconnection cannot be reduced, the use of distributed transmission was seen as economically impractical for all but a few special cases.

VII. CONSUMER ELECTRONICS ISSUES

31. As was shown earlier, the capabilities of the adaptive equalizer in consumer receivers will be largely determinative of the system design limitations. Clearly, to make distributed transmission practical in the large cell version that might appeal to

broadcasters, longer distance differences to adjoining transmitters than 4.5 miles will have to be accommodated. This means that adaptive equalizers longer than 24 microseconds will have to be available. But it seems unlikely that such long equalizers will be needed for the average broadcast situation. Thus it is also unlikely that consumer electronics manufacturers will be willing, on their own, to build longer equalizers into receivers. This suggests two possibilities if distributed transmission is to be used at all: the manufacturers can offer different levels of performance in the equalizer, passing the costs along to the consumer who wants or needs a longer echo time, or the FCC can mandate that all receivers must have equalizers meeting or exceeding some minimum length. (Such FCC intervention is not suggested herein.)

32. Assuming that the length of the equalizer is left to the marketplace and assuming that manufacturers are unwilling on their own to include equalizers longer than some value deemed adequate for normal, single-transmitter installations, the possibility exists to have differentiated receivers available to consumers. This raises several concerns, mostly economic in nature, about such matters as the cost of inventorying different classes of receivers based on the equalizer characteristics alone, the possibility of making additional equalizer capability available on a plug-in basis (never a good technique in the past for the consumer electronics industry), the problems of purchasing a receiver in a market with no stations using distributed transmission and then taking it to a market where one or more uses the technique, and so on. All of these concerns tend to weigh against the use of distributed transmission except in a few special cases.

VII. COMPETITIVE FACTORS

33. A television station considering the use of distributed transmission would have to include among the issues to be examined the competitive situation in which it would find itself. If all of the other television broadcast outlets in the market were able to build facilities using single transmitters, especially if those competitors' transmitters were located in proximity to one another, the broadcaster considering distributed transmission would have to convince a large portion of the audience that it was worth

their while to install rotators on their antennas in order to view that one station. This follows from the requirement, described earlier, for a 6 dB difference between primary and echo signals for the adaptive equalizers to work properly, and a knowledge that there will be large parts of the coverage area of a distributed transmission system with signals closer in amplitude than that. There will also be the need to convince the audience that it is worth their while to wait while the rotator turns as they switch to that one channel and back. All of this will put such a station at a competitive disadvantage.

34. On the other hand, if most or all of the stations in a market were to use distributed transmission, these competitive factors would cease to be problems. This would be especially true if all of the stations in a market were able to build and operate joint or collocated distributed transmission facilities. In such a case, the operational costs of distributing the signals to each of the transmitter sites could be shared and would no longer be burdensome, since all the stations in a market could fit onto a single fiber to each transmitter site. Also in such a case, viewers would not be bothered with rotators and delays in changing channels since their antennas would point to the same site for all stations in the community. This suggests the kinds of situations in which distributed transmission might be worthwhile, in spite of all of the impediments previously outlined in these comments.

VIII. POTENTIAL OF COFDM

35. As mentioned previously, some have suggested that Coded Orthogonal Frequency Division Multiplex (COFDM) is the answer to all or many of the issues raised above. Without passing judgement on the accuracy of the claims for COFDM, it is a system that uses no adaptive equalizer and is claimed to be able to work in an environment of echoes. In fact, it is claimed that, with application of the proper techniques, interference from adjacent transmitters carrying the same signals can be *constructive* rather than *destructive*. This means that gaps between the coverage areas of individual transmitters can be filled in through the ability of the receiver to sum the signals from both. Another important claim for COFDM is that, because it uses no

adaptive equalizer, it can receive signals with 0 dB difference in levels between them. The significance of this claim, if true, and if COFDM were implemented using distributed transmission, is that coverage throughout a station's service area could be achieved using "rabbit ear" dipole or monopole antennas. This would be most beneficial for portable and mobile applications. It might also avoid the need to use rotators in markets where some stations use a single transmitter and others use distributed transmission, at least in portions of the service area where the single transmitter signals are strong enough.

36. The claims for COFDM are enticing. But any serious examination of the technology will mandate thorough testing of complete systems including both source (compression) and channel (transmission) coding. This will be necessary because of the close coupling of the two in the systems that have been tested so far. It probably will not be possible for anyone, no matter how expert, to say with a certainty that combining an existing source coding system with COFDM used for channel coding yield the best result. This means that, if COFDM is to be considered, there will have to be a hiatus for a year, possibly more, while proponents develop the requisite interfaces, determine the necessary data rates, choose the best COFDM structures, build and integrate hardware, and conduct their own test programs. Then there will have to be testing of the sort conducted at the Advanced Television Test Center. Given the expenditures of resources to this point, it is unclear that any of the proponents would undertake such an exercise. Nevertheless, should the Commission decide for whatever reason that it is going to delay the selection and implementation of a system and allow for testing of COFDM, it would be most appropriate to test it for the kinds of characteristics and performance outlined in the preceding paragraph.

IX. POLICY CONSIDERATIONS

37. There are a number of policy matters that the FCC would have to address if it wishes to permit operation of ATV distributed transmission systems. While not an exhaustive listing, some will be mentioned here. First, the current Rules contemplate a

single transmitter as the mechanism for complying with the various requirements placed on broadcast facilities. For example, there is a requirement to put a minimum of a city grade signal over the city of license using the transmission facilities defined in the application for construction permit. To permit distributed transmission, this might have to be changed to require only that some prescribed minimum signal level be delivered over the city of license from whatever number of transmitters is required by the system design to achieve such a result. In calculating interference protection between stations, it is currently the practice to base the calculations of coverage area on the transmitter site and the appropriate power level and antenna height at that site. To permit distributed transmission, this might have to be changed to provide for a licensed service area for each station, the borders of which would be used in interference protection calculations in the future.

38. This discussion has concentrated on the results of the use of distributed transmission in the large cell scheme for reasons explained earlier. None of the limiting factors that have been outlined, however, in any way limits the potential for use of such techniques in a small cell approach to fill in gaps in coverage and to overcome terrain obstacles. For these applications, the use of on-channel boosters is likely to work well, given the small areas to be covered, the limited time delay differences between primary and repeated signals, and the use of adaptive equalizers and error correctors. The digital nature of the signals should permit as good a signal quality in such situations as in direct reception from the main transmitter. The Rules may require revision or interpretation to allow such on-channel boosters where currently only LPTVs and translators are permitted. Similar considerations would apply, of course, to the same Rules if large cell operation is to be permitted using same-frequency transmitters or on-channel boosters.

39. If distributed transmission were permitted, the possibility would exist to tailor the coverage within a station's designated service area to favor population centers and to avoid investing in transmission capabilities for regions with low population density. This could have public policy repercussions that might cause the Commission to require provision of service to some proportion of the service area within a particular time

frame. At the same time, allowing stations to begin with relatively small facilities just covering the city of license or some other fraction of the service area could be a means to ease the financial burden for particularly weak operations where there is little likelihood of the public receiving service through some other means. The Commission has yet to address the matter of minimum service areas in these procedings, and much can be accomplished through the construction of such rules.

X. CONCLUSION

40. The use of distributed transmission techniques will not be a panacea for all television operations that have difficulty in implementing Advanced Television. It may, however, provide solutions in certain specific cases where all the factors work in the right direction. For these reasons, as the Rules for Advanced Television are formulated, it is recommended that provision be made for those situations where broadcasters find distributed transmission to be their best solution. Especially in the early days of ATV operation, the Commission should encourage the experimentation that will lead to the best implementations and that will permit the largest number of broadcasters to participate at the earliest possible time. This will serve the Commission's goals of a speedy transition to ATV. Allowing distributed transmission, under appropriate guidelines that preserve the Commission's other regulatory objectives, will further these objectives.

41. The writer wishes to thank the Commission for the opportunity to bring to light the work of IS/WP-2 and SS/WP-1 in these areas and also to present his views. Any attention given to these comments is greatly appreciated.

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November 3, 1992

<u>**VIA TELECOPIER AND MAIL**</u>

Mr. S. Merrill Weiss
25 Mulberry Lane
Edison, New Jersey 08820-2908

Dear Merrill:

Enclosed with this letter is a report of a study I have made of an example of a distributed transmission system for ATV.

I have used the basic assumptions employed in the Lery, *et al* paper in the September issue of the IEEE Transactions on Broadcasting, but I have taken into account the ATTC/ATEL test results and have considered also the interference to the low power facility from the NTSC station. The result is not quite as optimistic as the Lery paper would indicate.

My conclusion is that the low power boosters will be useful in particular circumstances, but they are not necessarily the answer to extending ATV service, or of achieving broadly satisfactory service where the central transmitter cannot employ a tall antenna.

The report has been reviewed by Bob Keeler. I made a couple changes from my original draft to improve clarity. I shall be interested in your comments.

Best personal regards.

Sincerely yours,

Jules

Jules Cohen, P.E.

cc: Dr. Robert Keeler (with enclosure)

DISTRIBUTED TRANSMISSION OF ATV SERVICE HEIGHT/POWER/COVERAGE AND INTERFERENCE STUDY

Introduction

Pursuant to the request from IS/WP2, a study has been undertaken of the feasibility of using a distributed transmission system approach for the delivery of the ATV service. This paper deals with matters of antenna height, effective radiated power, the likely noise-limited coverage, and the interference-limited service area achievable. Preliminary examination of the scope of the problem showed that the use of a distributed transmission system was strongly dependent on the co-channel spacing applicable to a particular allotment. Accordingly, the initial study undertaken explored the conditions assumed in the recently published paper by Lery, *et al.*[1]

Assumptions

The ATV channel was assumed to be in the UHF band, 155 miles from the nearest co-channel NTSC station. The NTSC station was assumed to be operating with maximum effective radiated power of 5,000 kilowatts at the peak of sync, and with height above average terrain of 1200 feet. As illustrated in the accompanying diagram, such a facility would have its Grade B contour located 55.8 miles from the transmitter. Furthermore, a co-channel NTSC station at the minimum separation permitted by the FCC (155 miles), and with similar operating parameters, would cause interference to the desired station over a crescent with maximum penetration of 14.7 miles. The calculation of that interference crescent assumed a desired-to-undesired ratio (D/U) of 28 dB and a receiving antenna with front-to-back ratio of 6 dB.

Only the widely spaced ATV distributed transmission scenario was studied in detail. Since system proponents advise that an "echo" no stronger than 6 dB below the desired signal is required for reliable echo elimination, the use of small cells (the narrowly spaced distributed transmission scenario) would produce many sectors where satisfactory reception could not be achieved. Furthermore, the extensive delivery network required for serving the multiple cells is not likely to be achieved economically.

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[1] S.A. Lery, W.H. Paik, and R.M. Rast; Extending HDTV Coverage Using Low-Power Repeaters--a Cellular Approach; IEEE Transactions on Broadcasting; September 1992, Vol. 38, No. 3, page 145.

Planning factors employed are summarized in the following table. D/U ratios for the ATV system were derived from the only independent laboratory test results on a digital system so far made available to the public[2]. Other planning factors are as adopted by PS/WP3.

Planning Factor	NTSC	ATV
Receiver Antenna Gain (dB)	NA	10
Downlead Loss (dB)	NA	4
Dipole Factor (dB)	-22	-22
Thermal Noise (V)	2.6	2.6
Receiver Noise Figure (dB)	10	10
Antenna Front-to-Back Ratio (dB)	6	14
C/N Threshold Ratio (dB)	NA	16
ATV Required Local Field Strength (dBμ) (in absence of interference) (F50,90)	NA	44.6
ATV into NTSC D/U Ratio (dB)	35	NA
NTSC into ATV D/U Ratio (dB)	NA	7

NA: not applicable

Note: The outer limit of NTSC service in the absence of interference is assumed to be the Grade B contour (64 dBμ for UHF).

[2] DigiCipher HDTV Record of Test Results; Submitted to Advisory Committee on Advanced Television Service of the Federal Communications Commission by Advanced Television Test Center, Inc., Cable Television Laboratories, Inc., and Advanced Television Evaluation Laboratory; August 1992.

Calculation Results

The objective initially set for the ATV central transmitter, located 115 miles from the closest NTSC station, was to achieve interference-free service at a distance of 40 miles. At that location, 75 miles from the NTSC station, the NTSC F(50,10) signal strength is 65.3 dBμ. Taking into account the 14 dB receiver antenna front-to-back ratio and the required D/U ratio of 7 dB, the required ATV F(50,90) field strength for interference-free service is 58.3 dBμ. The following table shows the required ATV average effective radiated power required at four antenna heights to achieve that field strength at 40 miles.

ATV HAAT (feet)	**1 kW F(50,90)** (dBμ)	**ERP Required** (dBk/kW)
400	21.4	37.2/5250
600	25.4	32.9/1950
800	29.0	29.3/851
1000	32.2	26.1/407

In consideration of the power required at the several heights, the decision was made to employ antenna height above average terrain of 1000 feet. However, with 407 kW at 1000 feet, the ATV F(50,10) field strength at a point 14.7 miles inside the Grade B contour of the NTSC station would be 53.3 dBu. That is only 22.4 dB below the 75.7 dBu NTSC F(50,50) field strength at the same point. But, when the required 35 dB D/U ratio and the 6 dB receiving antenna front-to-back ratio are considered, the ratio of the NTSC F(50,50) signal strength to the ATV F(50,10) field strength must be at least 29 dB to avoid interference to the NTSC station. For the avoidance of interference, the ATV ERP must be limited to 19.5 dBk (89.1 kW). At that power level, the interference-limited service of the ATV station is at a distance of 36.0 miles from the transmitter at the point of maximum penetration of the NTSC interfering signal. The noise-limited ATV contour is at 45.4 miles from the transmitter. The noise-limited and interference-limited contours of the ATV station are shown on the accompanying diagram.

A low-power ATV (LPATV) booster station was then assumed to be located 35 miles from the main ATV transmitter to provide extension of ATV interference-limited service. Assuming a height above average terrain of 200 feet, the determination was made that the permissible ERP for the LPATV station is 5 dBk (3.2 kW) if the RMS interfering signal level at the interference-limited NTSC contour is not to increase by more than 0.5 dB.

With ERP of 3.2 kW and HAAT of 200 feet, the noise-limited contour would be at a distance of 23.0 miles from the LPATV transmitter. However, the LPATV facility would be subject to substantial interference from the NTSC station. Also, since receiving antennas located between the LPATV station and the NTSC station would have no antenna directivity discrimination against the primary ATV station, some portions of the LPATV noise-limited region would be subject to echo interference because the 6-dB ratio requirement would not be met or exceeded.

A cardioid pattern, similar to that assumed by Lery, *et al* was assumed here also for the LPATV antenna except that the back null was assumed to be filled to meet the FCC requirement of no more than a 15-dB front-to-back ratio. On the direct line from the LPATV station toward the NTSC station, the ATV interference-limited service would extend only 12 miles. The entire interference zone is shown by cross-hatching on the accompanying diagram.

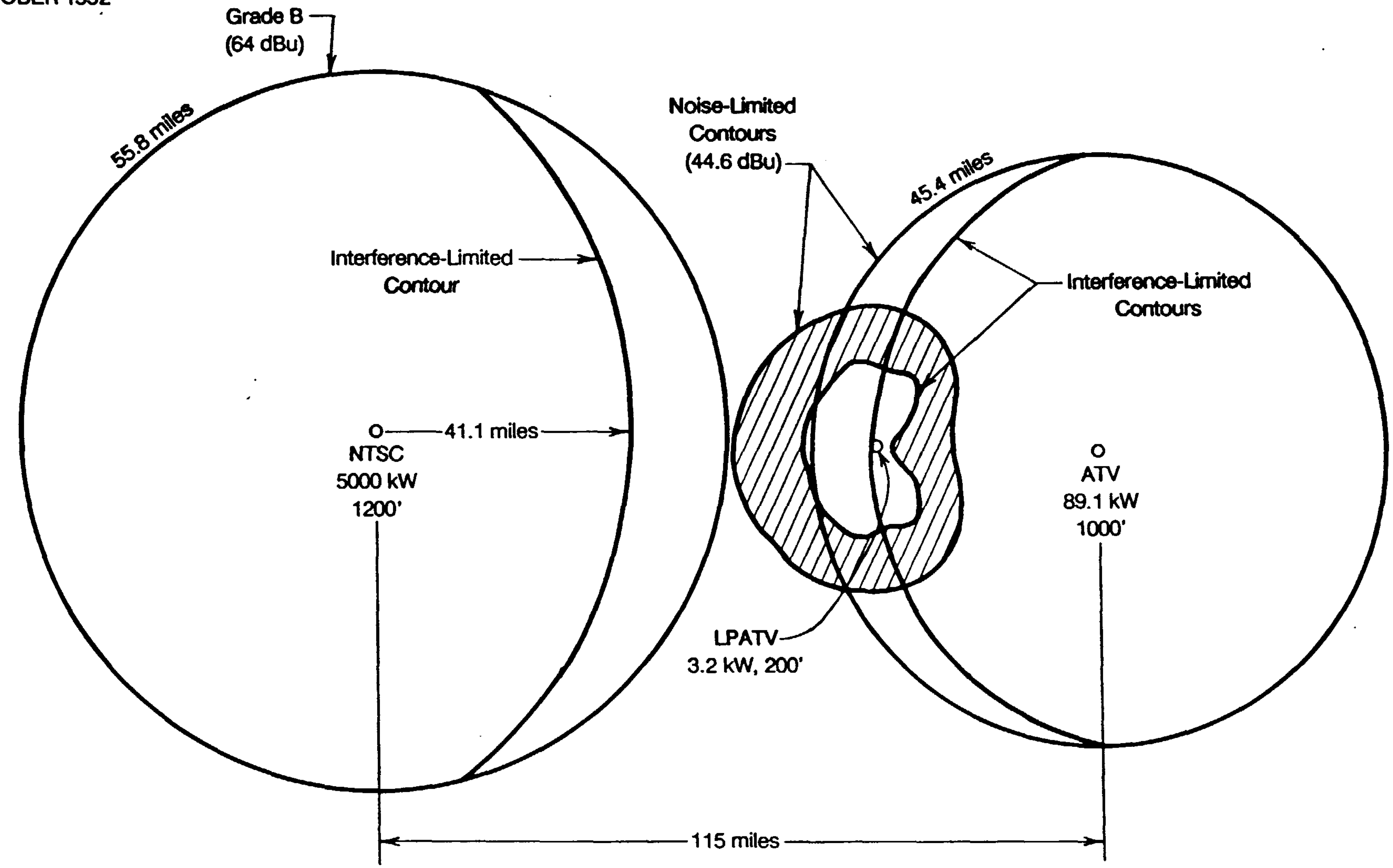
Conclusions

The utility of low-power, on-channel boosters is dependent on the particular circumstances of each allotment. In the illustration used, five boosters would be needed to eliminate the effect of interference to the ATV station from the nearby NTSC station and to provide a modest increase in interference-limited service. The most useful application would appear to be to provide service to a pocket of population not receiving such service. However, the facility would have to be tailored specifically for the application to avoid creating undesired interference where signal strengths from the main and booster station are not at least 6 dB apart.

November 3, 1992

Jules Cohen

OCTOBER 1992



STUDY OF POSSIBLE USE OF
LOW POWER FACILITY TO ENHANCE
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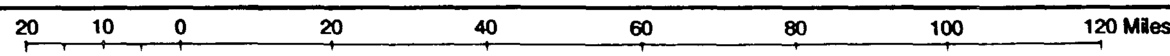

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MEMORANDUM

VIA TELECOPIER

To: Merrill Weiss

From: Jules Cohen JC

Subject: Distributed transmission of ATV service

Pursuant to your suggestion, I did a follow-on study to that reported to you in October. In the new study, I reduced the central facility to permit greater power by the boosters without increasing interference to co-channel NTSC stations.

In the new study, I assumed that the central facility should have an interference-limited service reach of 30 miles. The NTSC assumption, like that in the earlier study, was with ERP of 5 Mw, HAAT of 1200 feet and spacing of 115 miles from the ATV station. The ATV station was assumed to use antenna height of 600 feet AAT. Under those conditions of operation, the required ATV average power was determined to be approximately 35 kilowatts. The noise-limited radius for the ATV facility would be about 37.5 miles.

A booster station was then assumed to be located 30 miles from the central station and on the line to the NTSC station. HAAT for the booster was assumed to be 200 feet. Permissible ERP toward the NTSC station was found to be approximately 32 kilowatts. A cardioid pattern was assumed for the booster facility, as in the earlier study. For these assumptions, the maximum distance to the noise-limited contour of the booster is almost 30 miles. However, interference from the NTSC station would limit the maximum service radius to approximately 18 miles.

The conclusion of the new study is much like that of the earlier study. Although four boosters could be used around the periphery of the central station's service area to pretty well extend the useful range, many locations would suffer self interference in that the 6-dB ratio required for reliable operation of the equalizing filter would not be satisfied. Boosters can provide a more important role in the ATV service than in NTSC to bring a useful signal to areas with substandard service, but use of such boosters must be tailored to individual circumstances and can not be accepted as a universal solution to inadequate ATV service from a relatively minimal central transmission facility.

December 16, 1992